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SOLAR PROBE HELIOS, MISSION REQUIREMENTS AND APPLIED SPACE SIMULATION TECHNIQUES

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ABSTRACTS

The HELIOS Mission with maximum irradiation up to 16 S.C. requires special simulation techniques. The different simulation techniques and their realisation are described.

1. Introduction

The HELIOS A and B missions will be the first Deep Space Missions to attempt investigation of the sun's environment at, respectively, 0.3 and 0.25 Astronomical Units (AU). Since our knowledge of the sun's environment is only approximate, the specifications for Space Simulation must be based on assumptions.

Furthermore, it is not yet possible, for a full-size HELIOS model, to simulate the sun's radiation at the closest approaches of, respectively, 11 and 16 Solar Constants (SC). One is forced to use diverse simulation techniques in the attempt to attain maximum reliability in the spacecraft at minimum cost. The following text describes the newly constructed and/or modified facilities, test methods, and results.

2. The HELIOS Mission

Seven years ago, President L.B. Johnson and Chancellor L. Erhard agreed to proceed with a joint bilateral project for the research of interplanetary space. The "Memorandum of Understanding" between the U.S. and Germany was signed in mid-1969 (1); the development contract for the HELIOS probe was awarded to industry at the start of 1970.

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The launching of the probe, with a Titan III-D rocket, is planned for September 1974.

The first probe will be injected into an orbit in the plane of the ecliptic with the perihelion at 0.3 AU (1 AU = about 150 million kilometers), and will return to the aphelion at 1.0 AU in about 180 days (Fig. 1). If the first mission is successful, and the transmitted data indicates that a closer approach with this probe seems possible, a second probe will be launched 15 months after the first, with a perihelion of 0.25 AU. The periods of closest approach, occurring 90, 270, and 450 days after launch, will doubtless be most important. The solar radiation intensity, according to the inverse square law, will peak at 11 and 16 SC, respectively (Fig. 2), equivalent to 22.5 kw/m^2 at closest approach. Clearly, this can cause unusual thermal problems to arise - just consider the absolutely necessary ports for experiments and telemetry, the external attachments such as antennas, as well as the solar cells on the probe's surface.

The participation of several countries in the scientific aspects of the program underlines its international significance. The USA, Italy, and Australia are each supplying one experiment. The rest of the total of 11 experiments comes from Germany. The experiments will perform measurements ranging from electric and magnetic fields over a wide spectrum, to mass spectrometry and analysis of the zodiacal light.

3. The HELIOS Solar Probe

Since realistic simulation techniques are necessarily determined by the complexity of the specimen, a short description of the probe is in order.

Detailed information can be found in the references (2, 3, 4, 5). The 320 kg probe is spin stabilized and shaped somewhat like a spool of thread 2.8 meters in diameter and 2.1 meters high. For protection against heat, the middle section is super-insulated, however, this insulation layer must be breached for necessary ports and appendages. An active temperature control system using louvers (6) is situated over and under the cylindrical middle section; this system must protect not only against over-heating at closest approach, where the radiation intensity is 11 or 16 SC, but against the cold of outer space, where the intensity is only 1 SC. The solar cells are installed on the two diverging cones attached to the middle section.
In order to reduce the temperature, about half the area of the solar cells panels is covered with second surface mirrors. In addition to the thermal problems caused by the ports in the middle section, when the louvers are open at close approach the high-gain antenna reflector reflects sunlight and radiates heat (due to its own high temperature) into the probe compartment. An overall picture of the several measures for controlling

the thermal balance over the necessary temperature range is provided in Fig. 4. The measures reduce the over 100 kw of solar energy which strikes the probe to a residual of 500 w, to be dissipated by passive radiators and active louvers.

4. Environmental Problems

The intensity of evenly distributed radiation from a point source is inversely proportional to the square of the distance from that source. Using this ideal law the intensity can be calculated as a function of the known intensity at earth. This applies also to electromagnetic radiation and uncharged particles. The accuracy of the predicted solar flux will be influenced by uncertainties in the final achieved orbit and the accuracy of the solar constant. The different types of radiations, influenced even at great distances by the sun's wide-ranging electric and magnetic fields, are not well known - to measure them close to the sun is the aim of the HELIOS mission. The degradation effects of charged particles can only be estimated. The severest degradation and contamination (for example, outgasing from organic materials such as adhesives, and condensation of these gases on cooler parts) are expected at closest approach due to the strong ultraviolet radiation and temperatures up to 180°C on the solar panels (7, 8). Furthermore an inadequate simulation in the test facility can change these effects. For this reason, certain test facilities have been so constructed that contamination from the facility itself is held to an absolute minimum.

5. Test Philosophy and Sequence

In order to achieve maximum stability over the range of temperatures expected, it is necessary first to select or develop materials to withstand the extreme conditions, and to test them to exact specifications. At many facilities, especially at Goddard Space Flight Center (GSFC) at Washington, materials and components have been subjected to tests for absorption and emission (α, ε), outgasing, and heat conductivity at various temperatures - also under bombardment with charged particles. The following remarks will concentrate on thermal resp. solar simulation.

A space simulation facility, in which a full-size HELIOS model could be tested with 11 or 16 SC, is not available. The construction of such a facility for this special case is not feasible because of cost and time, not to mention development risk. Clearly, several compromises must be made. Step by step, the critical areas were isolated in which maximum of quality and reliability with minimum effort could be achieved. Logistic problems resulting in higher costs arose - for example, tests in the U.S.A. with all necessary ground support equipment.

Since true solar simulation for the full-size model was not possible, it was agreed to test critical materials and components at full intensity. For this purpose a U.S. solar simulator was ordered with the capability to produce 15 SC with a 30 cm beam diameter, filtered, and with high collimation. Also, in the Institut für Raumsimulation (DFVLR), a small chamber was modified by the addition of a motion simulator and an improved shroud. Uncertainty existed about the validity of extrapolation to 11 or 16 SC from tests at 1 to 2 SC (in 1970) or at 1 to 5 SC (later), because different heat transfers are superposed (thermal radiation prop. T^4, conductivity prop. ΔT) and the coefficients still have a certain temperature-dependence. In order to clarify and confirm the possibilities for extrapolation, a relatively simple 48-node small-scale model was constructed and tested at 1, 2, 7 and 11 SC. In these tests the temperatures obtained at 1 and 2 SC were mathematically extrapolated to 7 and 11 SC and compared with measured values (9, 10). These tests served also to provide practical experience in high-intensity measurements. The first test, in the IABG +) simulation chamber, uncovered systematic errors that, during the second test in the DFVLR chamber, could be eliminated by a more precise determination of the chamber-influences.

The results of these tests increased our confidence in the validity of extrapolation. However, the model was very much simplified and small (30 cm in diameter), hence the gained information limited. Besides component-tests solar simulation tests at natural size of HELIOS were envisaged in U.S.-chambers. The functional thermal/vacuum testing of the spacecraft (soak tests) and the thermal balance tests at the expected high and low orbit temperatures were performed in a German chamber under simplified simulation conditions. The flow plan for thermal testing is shown in Fig. 5. First, materials (e.g. solar panels and surface layers) and components (e.g. experiments exposed to space) are tested under spectrally-matched high-intensity radiation in the DFVLR component test facility. Next, complete sections, as well as the thermal model (TM), of HELIOS are tested in a modified vacuum chamber at IABG with simple infrared heating, without solar simulation and motion simulator (11). Final testing of the TM and prototype (P) is accomplished in the 25 ft chamber at JPL in Pasadena under high intensity (5.4 SC at 11 ft beam diameter). Problems which arise in the course of testing (e.g. high-gain antenna reflector) can be studied and corrected by repeating previous tests in smaller facilities.

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6. Summary of Simulation Methods

The possible simulation methods are listed in Fig. 6.

- o Solar simulation, e.g. an "off-axis" system using xenon lamps, allows the generation of collimated, spectrally-matched sunlight. Because of the enormous power required such facilities are expensive as investment and in operation. None exists capable of meeting HELIOS mission requirements.
- o Tube lamps, e.g. xenon low-pressure or tungsten lamps. The spectrum of tungsten lamps varies with the power, and cannot be matched to the sun's. It is difficult to achieve the correct energy distribution along the spin axis.
- o Simulation of the absorbed energy with heater tapes imbedded in the surface is often used for satellites near earth (1 SC); but for the high temperatures of HELIOS, this method is problematic. Since the heater tapes should not be left in the flight unit, the surface-panels have to be changed after the test.
- o A heated canister to warm the spacecraft to the expected surface temperatures is the simplest method. However, a realistic irradiation of the ports is not possible. Also, re-contamination due to outgasing from hot spots condensing on to cooler parts can occur in the small (3 cm) gap between the canister and the spacecraft.

The thermal testing in three stages has turned out to be practical, although temperature deviations between tests in different facilities have been recorded. These inconsistencies have been largely resolved by facility improvements (e.g. of infrared absorption) and reduction of disturbing influences (e.g. test adapter). As a result of the tests, a series of improvements on the spacecraft, especially on apertures and antenna reflector, were found necessary. Details of the tests and facilities are the subject of other presentations and will not be discussed here. This presentation is intended to provide an overall survey and to explain the relationship between the various tests designed to solve the critical thermal problems involved in the challenging HELIOS mission. Although the final results can only be demonstrated by the actual flight-data, the test program allows high hopes that the essential problems can be mastered.

In closing, the authors acknowledge the technical support of various organisations, especially Goddard Space Flight Center, Washington, but also Ames Research Center, San Francisco, and Jet Propulsion Laboratory, Pasadena.

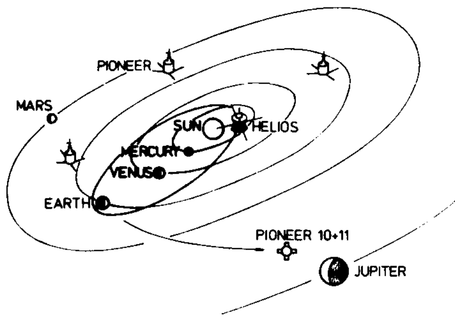


Figure 1

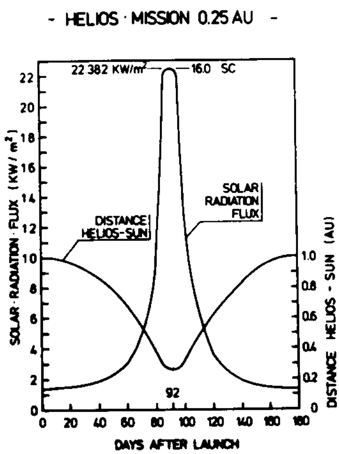


Figure 2

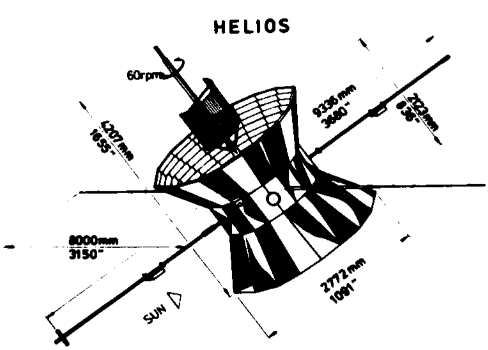


Figure 3

THERMAL BALANCE OF HELIOS AT 16 SC

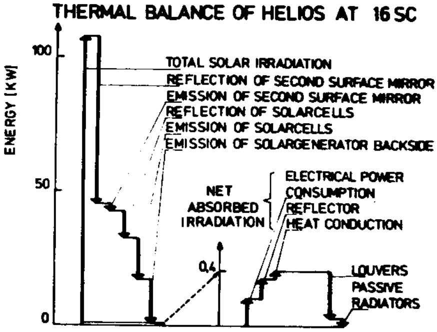


Figure 4

FLOWDIAGRAM OF THERMAL BALANCE TESTS
- DEVELOPMENT AND QUALIFICATION -

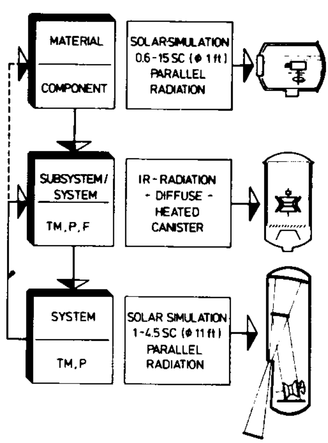
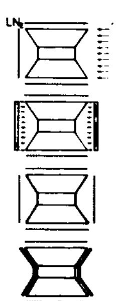


Figure 5

SIMULATION METHODS FOR TESTING THE SPACECRAFT



TYP	CHARACTERISTICS	REMARKS
SOLAR SIMULATION	COLLIMATED RADIATION SPECTRAL MATCHED	EXPENSIVE HIGH INTENSITY NOT AVAILABLE
TUBE-LAMPS TUNGSTEN, XENON CYLINDRICAL ARRANGED	RADIATION DIFFUSE NOT SPECTRAL MATCHED	HEAT FLUX ALONG SPINAXIS DIFFERENT
HEATER TAPES	TAPES IMBEDDED IN SURFACE	ELECTRICAL ENERGY EQUALS ABSORBED SOLAR FLUX
HEATED CANISTER	SURFACE TEMPERATURE OF SPACECRAFT ADJUSTED TO CALCULATED ORBIT TEMPERATURE	RADIATION PROBLEMS ON APERTURES

Figure 6

R e f e r e n c e s

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